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U.S. ARMY
DARCOM

U.S. ARMY RESEARCH OFFICE

PROGRAM GUIDE

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INTRODUCTION

This brochure describes research areas of interest to the Army. It replaces the ARO Program Guide issued in September 1981.

The ARO program is organized by scientific discipline, and the reader will note some overlap between sections. It should be kept in mind that the program is not limited to the topics listed, and proposals in other areas containing innovative scientific ideas and novel engineering concepts will be considered.

The research areas described may have short- or long-range impact on Army capabilities. If progress in certain areas requires the interaction of several investigators, and especially if an interdisciplinary approach is necessary, the Army Research Office will consider proposals for comprehensive research programs. Only a small number of such large programs can be initiated in a single fiscal year.

Proposals may be submitted at any time. We strongly encourage informal discussion and submission of a brief outline of the proposed research prior to the submission of a formal proposal. Key ARO staff members and their areas of responsibility are listed below.

Biosciences	Dr. Shirley R. Tove
Chemistry	Dr. George M. Wyman
Electronics	Dr. Jimmie R. Suttle
Engineering Sciences	Dr. Robert E. Singleton
Geosciences	Dr. Walter A. Flood
Mathematics	Dr. Jagdish Chandra
Metallurgy and Materials	Dr. George Mayer
Physics	Dr. Robert Lontz

Inquiries related to comprehensive and interdisciplinary programs should be addressed to the undersigned. For information concerning the format of proposals, evaluation procedures, reporting requirements, etc., please request a copy of the ARO brochure, "Guide for Unsolicited Research Proposals," which includes proposal forms. The ARO telephone number is (919) 549-0641. The mailing address is:

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BIOSCIENCES

I. Introduction

Extramural research in the life sciences is supported by the U. S. Army Research Office, the U. S. Army Medical Research and Development Command and the U. S. Army Research Institute for the Behavioral and Social Sciences. These programs are coordinated in the research proposal review process and by frequent contact and information exchange by staff members. A short description and the addresses of the latter two agencies are found at the end of this chapter.

Interactions of the biological world with the physical are all-pervading. They alter skilled task performance, affect the integrity of mechanical and electronic systems, alter man-machine cooperative efficiencies and increase logistics burden due to spoilage of rations and degradation of materials, thus increasing the need for resupply of repair or replacement parts. Valuable and, in some cases, uniquely applicable insights can be gained from the study of biological systems that perform functions or exhibit properties similar to those desired in manufactured systems of interest to the Army.

The ARO biosciences research program is currently oriented to the areas described below. Descriptive material shows some of the critical topics. Obviously, the lists are not exhaustive, nor can all of the topics be supported simultaneously. They do not constitute a shopping list for specific proposals. Rather the thrust areas and topics are intended as stimuli to your thinking. If you desire to pursue this discussion further, or if you have research ideas that you wish to bring to our attention, please contact either Dr. Shirley R. Tove (Microbiology) or Dr. R. J. Campbell (Biochemistry) by letter or telephone (919) 549-0641. We prefer that you submit a short, informal write-up of your ideas (1-2 pages) for a determination of Army interest and desirability of submitting a formal proposal. This informal proposal should include research objectives and the approach to the planned study. A small number of symposia, conferences and workshops are also supported in part or whole to provide interchange of ideas of value to ongoing programs of our laboratories.

II. Thrust Areas:

A. Combat Ration Research

Among the ration problems of military significance are long shelf life and the efficacy of a high-calorie, low-bulk combat ration. Since military rations need storage for long periods of time (up to three years), we need more research on basic mechanisms governing stability. The detriments to stability could be microbial, insect/rodent pests, autooxidation, or loss of nutritional quality. Research might include: the basis of resistance of microbial spores, suitable packaging, prevention of entry of pests. Biosensory means of pest control make use of species-specific chemical signals. Examples of problems concerning the high-calorie/low-bulk ration include: the potential problem of high fat diets, increased shelf life under high temperature conditions, assay procedures for small amounts of contamination.

B. Protection of Materiel from Biodegradation, Waste Conversion

Many microorganisms, bacterial and fungal, attack the materials from which Army materiel is fabricated. This attack, frequently upon mundane, ubiquitous items in the supply systems; e.g., sandbags and electronic connectors, contributes to both gradual and catastrophic failure of military equipment. Its contribution to the logistics problem of resupply and maintenance is large. Research is needed on properties of materials that make them susceptible or resistant to biological attack. The problems of commensal growth systems and the effect of the juxtaposition of several possible substrates on organism growth should be explored to better understand the field problem.

A major problem area is to balance protection of materiel for its usable lifetime with the need for rapid dissolution when it has become waste. Studies are needed on built-in means to destroy this waste by biodegradation or physical disintegration. The use of enzyme or other biological systems to achieve conversions of large scale wastes and by-products of military manufacture to useful products will be explored. Examples of major military disposal problems are food system wastes and the particular problem of aromatic nitro compounds from explosives manufacture.

C. Basic Research in Biotechnology

To take full advantage of the strong technological potential inherent in biomolecular engineering, it is necessary to further our understanding in a number of areas of basic research relevant to the structure and activity of various macromolecules. The foundation needs to be expanded with regard to the nature of protein-nucleic acid interactions, structure-function relationships in these and other macromolecules, characteristics of enzyme and membrane receptor active sites and their relation to peripheral site influence, and gene expression and its regulation in microbial, plant and animal cells.

For example, to what extent is primary, secondary and tertiary structural information essential for the capacity of proteins to function as enzymes or as membrane receptors for electrochemical gating? Can we duplicate or use the fine geometric control exhibited by enzymes or the sensitivity and specificity shown by receptors and antibodies? Can we mimic or improve on some of the known functions of proteins and other macromolecules or add new versions? Will these as-yet-unidentified substances serve a useful function in microelectronic devices or in new materials research? Can genes for selected proteins of defined properties be synthesized, cloned and expressed? What are the advantages versus disadvantages of using synthetic genes and recombinant DNA techniques, as opposed to solid-phase or other chemical synthesis, to manufacture proteins of desired qualities? Can we learn more about how genes are turned on and off, so production of specialty chemicals or other materials requiring elaborate stepwise treatment can be optimized in terms of regulation of sequential synthesis?

D. Defense Against Chemical and Biological Weapons

The continued threat of chemical and biological weapons requires basic knowledge of modes of action of potential agents on target organ systems. A number of agents act at the synapse to impede neural transmission.

Research on these various agents and systems will be used in finding improved means for contamination avoidance, detection and/or prophylaxis. Some areas for study are: basic physiology studies on affected tissues; transport across skin barriers; development of non-animal systems. There is a need for more rapid bio-analytical procedures to detect and identify potential agents in field environments. Finally, new biochemical approaches to decontamination of large areas without destruction of materiel in the process will be explored.

We will continue support for studies of neurosystems based on all possible molecular transmitters. The central nervous systems of higher animals are activated and controlled by various transmitter molecules acting at synaptic junctions. These control basic function and behavior in the animal. There are related processes, e.g., conductance and signal modification, disturbance of which can cause functional incapacitation. Research in this field might include study of transmitter synthesis, release, synaptic-receptor activation and blockade and existence of any system reset or compensatory mechanisms.

For biological agents, better understanding of agent composition, mechanisms and effects is required. Rapid detection of pathogenic organisms is a definite concern. Newly developed biosciences instrumentation now available offers increases in speed and sensitivity. Coupling of these instruments to computer-aided pattern recognition techniques may provide the opportunity for orders of magnitude improvement in rapidity and specificity of detection and identification. In addition to detection and identification, rapid and non-destructive techniques for decontamination of materiel are needed.

E. Sensory Factors in Performance Enhancement

The soldier in the modern military complex must be highly skilled in observing and interpreting input clues from his operational environment. Input is usually by visual and aural systems. The functional physiology and activity of these sensory systems to provide meaningful information are under continuing study. This provides a foundation for improved design of man-machine systems and operational techniques. An intriguing concept is the possibility of simultaneous input of data in man by two or more sensor systems. The effects on man of both impulse and continuous noise/sound at high intensities will continue to be studied.

F. Optimization of Physical Principles in Biological Systems

In many cases, a process or product-design approach which incorporates fundamental knowledge pertaining to basic theoretical principles and mechanisms underlying operation of biological systems may provide more effective alternatives to, or improvements in current items, or altogether new concepts, architectures, devices, etc. There is a need to increase the depth and widen the scope of this body of knowledge regarding biologically evolved and tested adaptations and solutions, to learn more about the types of processes and materials employed by various organisms, both plant and animal.

In fulfilling this need, for example, it is quite conceivable that progress in the fields of artificial intelligence, robotics and passive imaging could benefit from accelerated studies of brain mechanisms and architecture for parallel/distributed processing in cognition, of cell membrane signal transduction phenomena or of biological forms of readily retrievable information storage. Also, the biological world holds a strong lead in ability to detect traces of chemicals in the environment. The exact mode of such biosensory detection specificity and ultra-sensitivity is still a mystery. We hope that study here will help us detect and identify indicator chemicals and their sources in extremely low concentrations.

III. Other Related Army Funding Agencies

A. U. S. Army Medical Research and Development Command Program

For those proposals related to purely medical topics and those involving invasive testing in human subjects, the investigator is invited to contact the Commander, U. S. Army Medical Research and Development Command, ATTN: SGRD-RMA, Ft. Detrick, Frederick, MD 21701, telephone (301) 663-7414. The Army Medical Department research program divides into major areas:

1. Military Disease Hazards. Military preventive medicine, tropical diseases and malaria, ARBOR virus diseases, acute respiratory diseases, bacterial and mycoctic diseases, hepatitis, diarrhea, zoonoses and drug development.

2. Combat Casualty Care. Trauma, blood transfusion, burn technology, bioengineering, medical management in a toxic environment, combat surgery.

3. Health Hazards of Military Systems. Environmental medicine, physiology of adaptation, hazard assessment of military materiel, work and physical fitness, psychophysiology of vision and hearing, military psychiatry, aviation medicine, laser safety, microwave and ionizing radiation effects, military environmental stress.

4. Combat Maxillofacial Injury, Dental Disease and Materials. Oral disease prevention, maxillofacial surgery, dental material development.

5. Medical Defense Against Chemical Agents. Antidotes, patient decontamination, prophylaxis, treatment of chemical casualties.

B. U. S. Army Research Institute for the Behavioral and Social Sciences Program

Research in behavioral sciences, social sciences and training techniques for the Army is administered by the U. S. Army Research Institute for Behavioral and Social Sciences. Related inquiries or proposals should be addressed to the U. S. Army Research Institute for Behavioral and Social Sciences, ATTN: PERI-T, 5001 Eisenhower Avenue, Alexandria, VA 22333, telephone (703) 274-8641.

CHEMISTRY

Chemical phenomena and considerations pervade modern life in general and Army operations in particular. As the science of molecules, chemistry is involved whenever materials are produced, converted to energy or otherwise destroyed. It interfaces with many other disciplines, a situation reflected in the fact that a significant portion of the current chemistry program comprises contracts funded jointly with other divisions at ARO.

There exist a number of practical Army needs and desires, the fulfillment of which will likely or necessarily be based on molecular considerations; i.e., on advances in the field of chemistry. Each of the following descriptions of an Army Research Office interest is followed by a list of topics likely to have some bearing on the problem. It is intended to be representative but not exhaustive.

Rapid, thorough means to destroy chemical agents, other contaminants

Catalysis due to micellar structure, in microemulsions, at fiber or thin film interfaces, in oriented media; enzyme models; techniques enhancing nucleophile reactivity, especially toward pentacovalent phosphorus; photooxidation, electrooxidation; polymer bound reagents and catalysts; chemistry of and in foams and aerosols.

Rapid detection and identification of explosives and chemical agents

Electro-analytical techniques for sensing, detection and identification of trace components; chemically sensitive electronic devices, fluorescence probes, laser-induced fluorescence; mass spectroscopic techniques, including chemical field and laser-induced ionization and those requiring a minimum of sample preparation; photoacoustic spectroscopy; techniques especially applicable to organophosphorus and nitro compounds.

Greater protection for the individual soldier

New fibers and fabrics affording protection against weather, flame, chemical agents; absorption, scatter and reflection of electromagnetic radiation; dyes matching natural background; new barrier films, mechanisms of gaseous and liquid diffusion in films and fibers; mechanism of flame retardation; char formation; efflorescence, intumescence.

Quiet, efficient power sources with low thermal emission

Processes occurring at electrodes; chemically modified electrodes; new electrolytes, solid and liquid; electrocatalysis; new electrode materials, diaphragms; membranes; factors influencing dendrite formation, mechanism of passivation; ion transport, ionophores.

Deeper understanding of the chemistry underlying the effectiveness and responsiveness of propellants and explosives

Kinetics and mechanism of fast, highly exothermic reactions; new spectroscopic techniques to characterize and monitor same; nonequilibrium systems; ignition, initiation, activation and deactivation and meta-stable molecules; solid state unimolecular and intermolecular reactions; factors governing transition to detonation stage; combustion in high pressure regimes; efforts to examine representative model compounds, device theoretical models; catalytic decomposition of propellants.

New, more effective energetic materials and higher efficiencies in the production of energetic materials

Exploratory synthesis and characterization of nitro compounds, nitrogen-fluorine compounds, other fluorine-containing oxidizers; energetic plasticizers and elastomeric binders; synthesis and reactions of boranes and alkylcarboranes.

Unconventional approaches to nitration; oxidation by nitric acid; chemistry of the symmetric perhydrotriazine and perhydrotetrazocine systems.

New materials and ways to tailor properties of existing materials (see also M&MS Division)

Exploratory synthetic efforts: electroactive polymers, new resist materials (see also Electronics Division), materials for service in stressful environments, new composite matrix materials, new elastomeric materials, propellant binders; molecular structure/property relationships for materials.

Better fundamental insight into phenomena of known or potential practical utility

Triboluminescence; chemiluminescence; piezoelectricity; pyroelectricity; aerosols, smokes and foams, their formation, stability and spectroscopic properties; chemical means to produce coherent radiation, interaction of coherent radiation with compounds; reactions occurring at hot gas-solid interfaces.

Better understanding of surface and catalytic reactions

Reactions occurring at surfaces; model systems for surface reactions; techniques to monitor surface changes; low energy electron diffraction, photoelectron spectroscopy, inelastic electron tunnelling; electron energy loss spectroscopy.

Several of the topics outlined above (either in terms of the ultimate Army objectives or the scientific sub-areas) could very suitably be addressed by coherent, multi-faceted efforts involving two or more senior investigators. Discussions with ARO staff prior to the formulation of a formal proposal would be especially advisable in such cases.

The chemists at ARO welcome the opportunity to discuss research activities in order to determine where the interests of investigators and the Army may intersect. The list below is intended to assist the reader in choosing the most appropriate person at ARO to contact. All of us, however, stand ready to answer questions regarding relevance to the Army mission, or technical matters of a general nature, or to assist in the direction of an inquiry.

Dr. George M. Wyman - Spectroscopy, photochemistry

Dr. Bernard F. Spielvogel - Inorganic chemistry, electrochemistry

Dr. G. Ronald Husk - Organic chemistry, metal-organic chemistry, polymer chemistry

Dr. Robert W. Shaw, Jr. - Analytical chemistry, surface chemistry, chemical physics

Dr. Robert G. Ghirardelli - Colloid chemistry, stereochemistry

ELECTRONICS

I. Introduction

Research in electronics is performed in the areas of Microelectronics including semiconductors, magnetics, dielectrics, and circuit design; Communications and ISTA (Intelligence, Surveillance, and Target Acquisition) including networking and the theory, generation, transmission, propagation, reception, and processing of signals; and Computers and Information Theory including communications theory and computer architecture and software design. The objective is to identify and solve critical Army research problems where progress has been inhibited by a lack of novel concepts or fundamental knowledge. Work under this task has application to a wide variety of developmental efforts and contributes to the solution of technology-related problems in communications, command and control, surveillance, target acquisitions and night observation, intelligence and electronic warfare.

The following sections contain information on these research areas and some specific research thrusts. Due to the changing nature of technology, research objectives have to be flexible; therefore, the research objectives and thrusts described are not intended to be all-inclusive. If additional information is required for the submission of research proposals or briefs, potential investigators may contact the individuals responsible for the areas of research interest as identified.

II. Research Areas

A. Microelectronics

This research area includes the acquisition of basic knowledge and the characterization of electronic, magnetic, and optical materials. The Army seeks to understand those parameters of electronic materials which potentially affect or determine device performance. Areas such as generation, transport and control of charge carriers in semiconductors, magnetic phenomena, and electronics contributing to novel optical and electro-optical systems are of interest. Specific research fields of current interest are: electronic and structural properties of binary, ternary and quaternary semiconductors; semiconductor surface and interface studies; magnetic and quasi-optical effects at millimeter wave frequencies; and interfaces between optical fibers and other optical devices. (Contact: Dr. John Zavada)

The Army is also interested in the exploration of new or improved operating principles of devices in order to greatly improve performance and reliability while decreasing initial manufacturing set-up and continuing production costs. Studies of the fundamental limitions of the operating ranges of devices will provide directions for potential improvements. Included in this research effort is the evaluation of existing device barrier problems in the fields of generation, detection and processing of electronic signals. Research in semiconductor devices is emphasized to increase the power-frequency product or the bandwidth of electronic devices and to study transit time effects on semiconductor devices. (Contact: Dr. John Zavada)

Army electronics systems for the 1990s will require a five-order-of-magnitude increase in real-time signal processing capability. IC devices to satisfy this need must be at least 100 times faster than those targeted for the Very High Speed Integrated Circuit (VHSIC) program. Requisite device speed and densities demand that initial feature size be lowered from the current 4-5 micron (micrometer) level, through the VHSIC domain (1.5-0.7 micron), to the ultra-submicron region (0.1 micron and below). Research in this latter area has been named USER, Ultra Small Electronics Research. Planned, systematic technological realization of submicron and ultra-submicron devices cannot be achieved without prior derivation of the unique, non-classical relationships governing electronic behavior in such size domains. It has been shown that physical laws describing macroscopic diffusion, charge transport, interaction effects, etc., cannot be extrapolated into the submicron realm and are essentially useless at ultra-submicron dimensions. Research needs at this stage may be grouped in three major problem areas: (1) Carrier transport properties, non-equilibrium phenomena, and localized atomic effects; (2) synthesis and deposition of high-integrity thin layers of semiconductors, insulators and interconnects; and (3) holistic study of closely spaced, interacting structures, collective operations, dissipative relaxations, etc. (Contact: Dr. John Zavada)

The Army is interested in the following electronic component areas: (1) ultrafast digital switching transistors for high processing bandwidths in signal and data processing, (2) submicron memory components for higher complexity and fast access speeds in memory cache, microprocessor chip memory, etc., and (3) high frequency microwave/millimeter-wave transistors for communications (both discrete devices and monolithic integration). Research in support of these objectives includes: submicron device modeling and scaling, novel device structure concepts (e.g., vertical integration, ballistic devices and quantum-well concepts), submicron device fabrication for enhanced functional throughput rates as well as small power-delay products and diagnostic IC fabrication. Processing that complements these device studies is also of interest, in particular: fine linewidth etching, lithography, metalizations and electronic materials deposition. (Contact: Dr. John Zavada)

While programs on millimeter wave sensors and detectors are forthcoming, the state-of-the-art in millimeter wave componentry, particularly that of non-reciprocal devices, is very much in its infancy. Novel approaches in resonant and non-resonant interactions of millimeter wave energy with magnetic thin films are being sought. Quasi-optical and magnetic effects will be considered. In the area of far infrared research, the major effort will be devoted to the understanding and control of mercury cadmium telluride, its metallurgical as well as electronic properties. The understanding of the dependence of electronic and optical stability on structural perfection and on prior processing history is of great interest. (Contact: Dr. John Zavada)

Very large scale integrated (VLSI) circuits present challenging design problems. The Army supports research in the area of computer-aided design of integrated circuits leading to completely automated design for custom VLSI circuits. The goals of this research should be to reduce design time and cost and improve reliability of designs. Specific topics such as multilevel design, on-chip testing and verification, modeling of submicron devices, process modelling, techniques to increase computational efficiency, transmission line modelling, placement, routing, and mask generation are important. (Contact: Dr. William Sander)

It is recognized that there is a need for original research to produce novel circuit designs using new approaches in device technology. Improvements are sought in areas such as reduced noise and power dissipation and improved operating speed. Circuits such as detectors, amplifiers, phase-locked loops, voltage controlled oscillators, digital-to-analog and analog-to-digital converters, acoustic wave and electro-optic devices may benefit from this research. Of specific interest are wideband amplifiers, amplifiers capable of fast tuning, fast frequency synthesizers and large time-bandwidth devices. (Contact: Dr. William Sander)

B. Communications/ISTA (Intelligence, Surveillance and Target Acquisition)

This research area is concerned with the application of communications theory, electromagnetic theory, signal processing and mathematics to the fast, accurate, reliable and efficient transmission and acquisition of information.

Army digital communications networks are highly dynamic in the sense that the status, number, and geographical locations of nodes are continually changing. Also, similar links in a network can have widely varying capacities due to jamming and interference. The network design must consider these dynamics and message priorities in order that the network will continue to function, albeit at degraded levels. Specific interest is in the design of large distributed radio and cable networks including topics such as throughput in packet radio networks, distributed routing and control, and network synchronization. (Contact: Dr. William Sander)

Research in spread spectrum techniques is important to Army communications and intelligence, surveillance, and target acquisition systems. Improvements in speed of acquisition and synchronization, and coding are sought. Development of performance metrics and techniques for design analysis for both frequency hopping and direct sequence systems are needed. Improved coding properties for multiple access including code length, number of sequences, and correlation properties are sought. Techniques for detection and identification of spread spectrum signals are also emphasized. (Contact: Dr. William Sander)

Efficient digital signal processing algorithms and realizations which are amenable to implementation in VLSI circuits used to perform communications and intelligence, surveillance, and target acquisition functions are emphasized. Of particular interest are the use of concurrency to obtain high throughput, improved signal quality, reduced computational complexity, modular structures, and standard cell implementation. Multidimensional signal processing and adaptive estimation with emphasis on stability are important. Image modelling and target detection, identification, and moving target tracking are emphasized as well as are optical, acoustic, electro-optical, and acousto-optical signal processing. (Contact: Dr. William Sander)

The Army desires to expand the basic knowledge of electromagnetic radiation, propagation, and detection in areas which will impact on navigation, radar, electronic warfare, communications, radio direction finding, antennas, and electronic countermeasures. Full understanding and efficient use of antennas, atmospheric/ground propagation, and sensitive, optimized detection schemes are sought. Included in our interests are studies of the launching of waves in waveguides and propagation for the millimeter to optical spectra; radar resolution enhancement and target detection (classification in a clutter environment); and electrically small and conformal antennas with emphasis upon proximity effects due to nearby structures; coupling phenomenology of microwave and millimeter wave energy into complex structures, circuits and systems. (Contact: Dr. James Mink)

Research is also supported to provide a technology base from which complete low-cost high-performance millimeter/submillimeter wave integrated systems, including antennas, may be devised. For practical low-cost systems, one is not able to extend conventional wave-guide technology into the millimeter/submillimeter wave region because of the dimensional tolerance and the hand assembly required. The research will emphasize planar technology which allows one to fabricate a complete system function, including active, non-reciprocal, and passive devices utilizing processes such as lithography similar to those developed for standard IC devices. (Contact: Dr. James Mink)

Another thrust is optical communications in which the goal is to utilize optical techniques within distributed multichannel, wide-bandwidth communications command and control systems. Included within this effort are techniques which lead to high-speed optical signal processing and information transmission in the optical domain including mode control and interfacing techniques for optical fibers. System functions which may be performed optically are multiplexing/demultiplexing, branching, and address coding/decoding. (Contact: Dr. James Mink)

C. Computer Science

Computer systems in the Army are of two categories, distributed and embedded. Distributed systems consist of many computers connected to cooperate in the collection, storage, processing and dissemination of a variety of information. Embedded computer systems consist of computers, one or many, which are an integral part of the electronics of a larger system.

The distributed computing environment is characterized by large numbers of heterogeneous computers with dynamic configuration changes. Research interests include, but are not limited to, system design and analysis methods, concepts for network operating systems and distributed databases and techniques for analyzing and improving system reliability and survivability.

The embedded computer environment is characterized by applications requiring high throughput, high reliability, and specialized algorithms. Research interests in embedded computer systems include, but are not limited to, microcoding techniques and configurable architectures. This includes special purpose architectures for image detection, analysis and tracking.

Also of interest are investigations of methods for translating special purpose problem requirements into architectures amenable to VLSI implementation.

Research in software is required to support all computing activities in the Army. Research interests in software include, but are not limited to, design and analysis methods, measures and environments. Particularly of interest are methods for improving the life cycle cost through improved software reliability and maintainability.

Research in man and computer interaction is required to allow personnel with limited technical training to use computer resources effectively.

Research in artificial intelligence and robotics is encouraged with emphasis on the development of concepts to support computer understanding and computer-assisted decision making in a distributed computing environment. (Contact: Mr. C. Ronald Green)

ENGINEERING SCIENCES

I. Introduction

Research supported by the Engineering Sciences Division is concerned with a broad spectrum of fundamental investigations in the disciplines of solid mechanics, fluid dynamics and combustion sciences. Solid mechanics includes a wide variety of research areas such as impact and penetration, finite deformation, waves and shocks, fatigue and fracture mechanics, tribology, kinematics and mechanisms, structures, dynamics and vibrations and composites. The fluid dynamics research is primarily concerned with research in the areas of gas dynamics, rotorcraft aerodynamics, missile/projectile aerodynamics, aeropropulsion and blast waves. The research program in the combustion sciences area is focused on engine combustion, fuels, propellants and explosives. The following narrative describes the details of the scope and emphasis in each of these disciplinary areas.

II. Solid Mechanics (Dr. Edward A. Saibel, Dr. Frederick W. Schmiedeshoff)

Solid mechanics deals with the response of solids to static, dynamic, thermal and electromagnetic loads and the various types of interaction between solid objects in relative motion to one another. Also included is the analysis and design of mechanisms, machines and structures for performing various useful functions.

A. Impact and Penetration

High strain rate effects due to impact and penetration by hypervelocity bodies or strong blast fields are emphasized. Such phenomena as shear band formation, elastic-plastic and viscoplastic effects, crack formation and propagation, spall and penetration phenomena for both normal and oblique impact are all included. Models for complex 3-dimensional interactions are needed to develop the necessary understanding of these very fast phenomena.

B. Finite and Deformation, Waves and Shocks

Research needed in this area is concerned with quantitative evaluation of the state of stress and strain in the interior of a solid which is subjected to external forces and/or thermal, magnetic and electrostatic fields. Such situations may arise in the service life of Army structures in the field or in a metal-forming process utilized in the manufacture of some Army materiel. The forces in general may be either steady state or fluctuating, and research in this field would deal with studies of wave propagation, particularly 3-dimensional large amplitude motion, nonlinear behavior of finite strains, interactions of nonhomogeneities and inclusions and constitutive relationships, for example. Applications of both the methods of continuum mechanics and molecular dynamics are appropriate. Effects of thermal loads or electromagnetic fields may also be important, as in electromagnetic propulsion devices and should be addressed. Experimental methods, such as photoelasticity, photoplasticity, strain gauges, holography, acoustic and exo-electron emission and Fourier transform infrared spectroscopy, for analyzing the state of materials are needed for better quantitative determination of material response to assist in design.

C. Fatigue and Fracture Mechanics

In order to determine service lifetimes of Army equipment, better and more realistic theories of fatigue and fracture are required, especially a determination of criteria for failure under complex loading with realistic geometries. Studies on residual stress in structural elements, crack tip stress fields and dependence of crack propagation on material properties are needed for all types of construction materials. Concepts for in situ crack detection in metals and polymers are needed.

D. Triobology and Surface Phenomena

This research area is concerned with the friction and wear of interacting surfaces of solids with or without lubrication and the interaction of surfaces with corrosive or high temperature plasma environments. Determination of near surface stresses for smooth surfaces, the effects of surface asperities, fretting and wear on high speed surface contacts and high speed sliding friction are all included. The effects of debris in lubricants are important for determining surface integrity and require study. Plasma surface interactions, in which thermal loads, change of phase (ablation) and stress levels at velocities exceeding 3 Km/sec must all be considered for adequately describing surface response, are important for electromagnetic propulsion devices.

E. Kinematics and Mechanisms

This program is concerned with the analysis of motion of connected elements in relative motion, planar and/or spacial. The elements may be rigid or deformable. They are put together so as to follow prescribed paths with prescribed velocities and accelerations and to cover desired areas or volumes. Research topics in this field would include, for example, nonlinear dynamics of systems, optimal mechanisms, gear tooth design and mechanical or fluid power transmission concepts. Such studies as these form the basis for the analysis and design of machines, robots and the transfer of power from a source to a point of operation.

F. Structures, Dynamics and Vibrations

Methods of analysis and design of structures which will support or withstand static and/or dynamic loads and improve crash worthiness are required. For this purpose, properties of materials and values of pertinent material parameters must be determined. Included in this area are projects on stress, strain and motion analysis of structures with a goal of developing lighter, more reliable and safe structures. The dynamics of structural elements must be considered for improving stability and response of Army structures to various loading conditions. Vibratory response of structures, vibration prediction and suppression and vibration modelling are all important research topics in this area. The dynamics and vibration of multiple connected deformable bodies is a major consideration particularly with rotating elements.

G. Composites

Particular attention is being paid to composites as a means of optimizing material properties such as strength-to-weight ratios and dispersion of undesirable waves in structures such as those due to impact and thermal shock. Particular aspects of composites which are of interest are the choice of materials, fiber orientation and volume fraction of fibers for a particular structural function. Textile science is being used to obtain unique cloth with intricate weaving and mix of fibers which can be shaped and impregnated with a matrix. These composites need study at both the macro and micro level so that material properties and response to forces and temperature can be determined.

Several specific research areas which need special attention are wear erosion, surface phenomena in electromagnetic propulsion devices, kinematics and mechanisms, structural dynamics and impact and penetration.

III. Fluid Dynamics (Dr. Robert E. Singleton)

Research in fluid dynamics is oriented toward the development of improved or new technology for advanced helicopters, small gas turbine engines, maneuverable high speed missiles and high performance projectiles. Consequently, general research studies are needed for turbulent boundary layers, especially separated flows, both inviscid and viscous unsteady flows, interference phenomena of 3-dimensional configurations and computation aspects for various complicated flow fields.

A. Rotorcraft Aerodynamics

Specific investigations are required for better understanding and prediction of rotor wakes which must include investigations of vortex dynamics in a wake environment. The determination of ground effect on wake structure and formation and the resultant effects on blade aerodynamics and stability and control also demand increased attention. The effects of forward flight require additional study, particularly the blade vortex interaction and its consequences to noise and vibration. Configurational effects such as main rotor/tail rotor interactions or main rotor/fuselage interactions are also areas of research interest.

B. Missile Aeromechanics

Research in missile aeromechanics is needed to better define 3-dimensional flows past canard-body-fin geometries including body vortex shedding mechanisms, base flow and plume effects. Of special importance is the aerodynamics of rapidly maneuvering missiles in transonic flow as well as new designs for accommodating hypersonic flight. For high performance projectiles, research is needed for 3-dimensional viscous effects on boattails and near wakes, shock boundary layer interaction, hypersonic and transonic flows, base drag prediction, multi-shocked flow fields, fin-body interference and unsteady inviscid aerodynamics.

C. Small Turbomachinery Aerodynamics

Research related to flow fields in small radial and axial compressors and turbines requires an added emphasis in order to confidently design high-pressure-ratio low-mass-flow machines for either automotive or rotorcraft application. Investigations are needed on the highly complex and 3-dimensional flows in highly curved and swept ducts and channels, secondary flow patterns, compressor-diffuser interfaces, heat transfer mechanisms on cooled turbine blades, unsteady effects peculiar to these machines and variable geometry and end-wall configuration effects. Of special interest is the experimental measurement of flow details in these complex flow passages.

D. Blast Waves

Research on blast waves is concerned with the wave structure upon diffraction and reflection from various solid or porous geometric shapes. The effects of the ground plane, dust lofting, potential viscous effects and thermal conditions are also important elements needing further research. The propagation of blast waves into and out of buildings and focusing of blasts due to multiple interfering structures needs additional research. Of course, since loads, moments and overpressures are the important output quantities in these areas of research, both pressures and wall shear stresses need to be predictable in a variety of environmental conditions allowing for suitable designs for blast environments as well as determining realistic estimates of structural response and estimated damage.

IV. Combustion Sciences (Dr. David M. Mann)

A. Engines and Fuels

Research on combustion in engines is focused on intermittent, reacting flows encountered in diesel combustion chambers and on continuous combustion characteristics of small, gas turbine combustors. This focus leads to a strong emphasis on fuel injection processes, jet breakup, atomization and spray dynamics and subsequent heterogeneous flame propagation. Research on heterogeneous flames requires supporting study into kinetic and fluid dynamic models, turbulent structures, soot formation and destruction, flame extinction, surface reactions, multiphase heat transfer and other factors which are critical to an understanding of engine performance and efficiency. Of particular importance is the effect of variation of fuel properties such as aromatic content, viscosity, etc., on combustion processes, since such variations must be considered in development of multifuel engines. Additionally, some research is necessary to characterize the behavior of non-petroleum alternative fuels to provide a basis for selection of viable candidates. A related concern is the stability of engine fuels, both in long-term storage and in high temperature operation.

B. Propellant Combustion and Explosives

A small research program addresses propellant combustion processes which occur in gun propulsion systems. Research topics include, for example, the ignition and combustion sequences in liquid and solid propellants, the multiphase flow processes in granular and stick propellants, the down-bore, multiphase, turbulent, reacting flow adjacent to the barrel surface and subsequent competing processes for heat transfer to the surface, the modelling of multiphase flows, diagnostic techniques and ignition processes of the modern low vulnerability ammunition propellants. Another small research program in explosives is concerned with shock wave ignition in solid explosives, deflagration to detonation processes, energy partitioning in explosive phenomena and other topics related either to the safety or efficiency of explosive materials.

GEOSCIENCES

I. Introduction

The Geosciences Division supports research in the atmospheric and terrestrial sciences, that is, the physical sciences of planet earth excluding ocean media. The continental environments involved cover the entire range from polar to mid-latitude to tropical and the spectrum of natural and man-modified surfaces, perpetual snow or ice, tundra, deserts, rivers and lakes, forests, etc., and under all weather conditions, favorable and adverse, clean air and polluted air. The atmospheric sciences and terrestrial sciences are by nature highly interdisciplinary. Atmospheric and terrestrial problems that are of concern to the Army have increasing need for attack by interdisciplinary research teams. For more specific information on the program of the Geosciences Division, contact Dr. Walter A. Flood (atmospheric sciences) or Dr. Steven J. Mock (terrestrial sciences).

II. Terrestrial Sciences

The terrestrial sciences program addresses Army problems arising from the variable characteristics of the terrain. This is admittedly an extremely broad and diverse subject area ranging as it does from seismic propagation in soils to techniques for automated mapping. Three major research categories or thrust areas are delineated with examples of major problems.

1. Properties of Earth Materials

a. Soil and rock mechanics and dynamics (including snow and ice): This is an area of extreme importance to all phases of military construction from expedient field fortification to permanent facilities. Of particular interest are:

(1) Constitutive relationships under static and dynamic loading including 2- and 3-phase systems.

(2) Methods for testing and measuring properties in situ.

(3) Relationships between laboratory measured properties and those in situ.

(4) Stress wave propagation in unconsolidated, anisotropic media.

b. Novel techniques and instrumentation: Remote (non-contact) and emplanted sensors or systems which can measure properties in-situ are highly desirable. Particularly of interest are methods for determining the complex dielectric constant as a function of depth in the near surface (down to 100 meters), for detecting small scale anomalies, such as tunnels or caverns and for measurement of seismic and electromagnetic anisotropy.

2. Earth-Fluid Dynamic Processes

A continuous dynamic interaction between solid earth materials and the most abundant fluids, water and air, takes place at the earth surface and below the surface. Military problems arising from these processes include localized flooding on the battlefield, wave and tidal action on amphibious operations and port and harbor installations, natural or battlefield-induced dust as a function of soil properties and vehicle-induced susceptibility to erosion of terrain. Specific areas of interest include:

a. Soil Moisture: Questions remain as to whether the physics of time-dependent water movement in soils having sporadic surface inputs is well enough understood to successfully develop adequate soil moisture predictive models. Research is desired in the following areas:

(1) Experimental and theoretical studies of time-dependent vertical movement of moisture with variable inputs.

(2) Methods to measure/monitor soil moisture (a) by remote means, (b) with emplanted sensors or (c) combinations to these.

(3) Spatial variation in soil moisture as a function of terrain, soil types and microclimate.

b. Rainfall-Runoff Modelling: Streamflow modelling has reached an advanced state in civilian use for flood forecasting and routing. The military addresses a more difficult problem, namely forecasting runoff in small to medium sized ungaged basins. Specific research areas are:

(1) Parameterization of stage frequency as a function of basin characteristic and antecedent conditions.

(2) Adaptive hydrologic models for sparse data areas; i.e., which of the available hydrologic models are best used in areas having variable topography, vegetation and amounts of data.

3. Remote Sensing and Mapping

Research interests in these areas of the terrestrial sciences include:

a. Novel concepts and techniques for remote measurements and interpretation of surface and subsurface properties and anomalies.

b. Theoretical and experimental studies leading to terrain modelling, sensor modelling and feature signatures in frequencies from microwave to ultraviolet in relation to feature extraction, reference scene generation and simulation.

c. Image (and other) sensor interpretation and processing research directed toward automation of the mapping processes from image acquisition to data base preparation, map and other terrain display products.

III. Atmospheric Sciences

The atmospheric sciences program is subdivided into four major research categories: (1) Atmospheric Effects on Propagation, (2) Atmospheric Sensing and Probing, (3) Small Scale Atmospheric Processes and (4) Aerosol Research.

1. Atmospheric Effects on Propagation

Active and passive electromagnetic systems operating at wavelengths ranging from the centimeter through the ultra-violet as well as acoustic systems are performance limited by weather and battlefield conditions. Examples of propagation effects of interest to this Division include absorption by gasses, absorption and scattering by natural and battlefield aerosols and as a consequence of adverse weather, turbulence and battlefield turbidity, the degradation of the mutual coherence function and the contrast of images and targets.

The effects of realistic atmospheres and realistic terrain on the long range propagation of sound waves is another area of interest to this office. Modelling efforts, backed up by complete path characterization, are required to predict, with high accuracy, among other things, noise level contours around Army training centers.

Whether investigating EO system performance or acoustic wave propagation, it should be clear that experiments should be accompanied by extensive micro-meteorological measurements as well as a complete description of the particulates suspended along the propagation path. Furthermore, the relationship among the micro-meteorological parameters, the larger mesoscale weather conditions and the local terrain features should be established.

Research is also required in the reflection/scatter and backscatter from vegetation and snow-covered terrain at near millimeter wavelengths (0.85 to 3.2 millimeters). Particular attention should be paid to the physical consequences of the small antenna "footprint" and its effects on the statistics of the forward scattered and backscattered return; the effects of antenna polarization should be carefully investigated.

2. Atmospheric Sensing and Probing

Potentials exist for advances in remote and in situ atmospheric sensing and probing, for real-time surveillance of atmospheric conditions and parameters. There are indications that this can be accomplished economically, and with spatial and temporal resolution and precision not attainable with traditional techniques. Further development of these techniques applicable to problems in the preceding thrust areas is needed. Of special interest are:

a. Techniques for remotely measuring the optical properties of the atmosphere including natural and man-made aerosols.

b. Techniques for automated, remote measurement of meteorological parameters; e.g., precipitation, temperature, humidity, cloud height, horizontal and slant range visibility, pressure, wind, windshear and turbulence.

c. Techniques for remote and real time sensing of chemical and biological agents in the atmosphere.

3. Small Scale Atmospheric Processes

Primary interests in the meteorology of small scales of space and time are in developing techniques and mesoscale models of the atmosphere for depiction and prediction of meteorological conditions over the battlefield. Research efforts will be concentrated on:

a. Processes controlling formation and dissipation of fogs, clouds and precipitation.

b. Terrain effects on the planetary boundary layer and meteorological conditions.

c. Horizontal, slant and vertical variability of atmospheric elements.

d. Models capable of predicting transport, diffusion, scavenging and interaction of natural; e.g., dust and smoke, and man-made materials (including chemical and biological agents) released into the atmosphere in complex terrains and/or under adverse weather conditions.

4. Aerosol Research

The Army requires increased knowledge of the atmosphere as an aerosol system: characteristics of the aerosols, their involvement in meteorological processes and the effects of natural and manmade aerosols on visibility, obscuration and the transmission of electromagnetic energy. Research will emphasize:

a. New concepts for determining, analyzing and characterizing natural and man-made solid and liquid particles in the atmosphere including the origin, size, concentration, shape, orientation, composition, source and sinks, frequency of occurrence, temporal and spatial variations and deposition and scavenging.

b. Processes of formation, growth and dissipation of natural (fog, cloud, precipitation) and man-made aerosols (smoke, dust).

c. Improved methods for characterizing the aerosol environment of the battlefield.

MATHEMATICAL SCIENCES

1. Introduction

Mathematical techniques pervade research, development, testing and evaluation problems encountered by the Army. Furthermore, increasing demands are being placed on research in mathematics because of its fundamental role in the analysis and modelling of problems arising in Army science, engineering and operations. To meet these increasing demands, the mathematical sciences program of the Army Research Office attempts to systematically advance fundamental knowledge in mathematics that will meet present and future Army needs. To accomplish these objectives, the program supports an extramural basic research program by highly qualified investigators in many areas of applicable mathematics. Based upon the present and projected needs of the Army, the research program in mathematics is organized in four broad sub-areas:

- Applied Mathematics and Analysis
- Numerical Analysis and Computing
- Statistical Methods and Applied Probability
- System and Control Theory, Modelling and Artificial Intelligence

In the following paragraphs, specific program objectives are described in the four sub-areas mentioned above. A summary of current priorities follows. Clearly, the program does not cover the total spectrum of mathematical research in any particular subfield. Rather, it attempts to concentrate on those topics which appear to have impact on relevant Army problems in some reasonable time frame. The emphasis of the program, therefore, is reflected through a judicious mixture of both short- and long-term goals. In the descriptions which follow, an attempt has been made to relate research areas to functional areas. There will be unavoidable overlaps between various sub-areas, but the differences in major thrusts are appreciable enough to warrant separate descriptions. Prospective investigators are encouraged to contact Dr. Jagdish Chandra, Director, or Dr. Robert Launer, Associate Director, for further information.

A. Applied Mathematics and Analysis

This research program seeks to provide a fundamental understanding of the qualitative features of the basic equations of classical applied mathematics and modelling of physical processes that are of potential interest to the Army. Specific motivation, thus, comes from such problems as wave propagation through complex environments, combustion and explosion dynamics, transport and dispersion of contaminants, penetration mechanics and aerodynamics. A significant portion of these problems requires study of ordinary or partial differential equations in complex geometries. Therefore, the major thrust in this sub-area is on the mathematical analysis of nonlinear systems with special stress on analytical and approximate methods for multi-dimensional nonlinear partial differential equations.

B. Numerical Analysis and Computing

Research in numerical analysis is devoted to the understanding and development of efficient and accurate numerical schemes and to the associated issues relating to scientific computing and high quality mathematical software. Many Army problems give rise to mathematical models whose exact solutions cannot be analytically expressed and must, therefore, be approximately obtained. In other cases, exact solutions must be accurately and stably evaluated. Examples of the first class include many of the problems mentioned in the applied analysis area while examples of the second class stem from classical linear theory and statistics. The research thrusts in numerical analysis and computers include the development and analysis of methods for partial differential equations--especially nonlinear and time dependent PDEs and those arising from special areas such as fluid mechanics, aerodynamics and chemical kinetics. Complementary to this is the development of the underlying technologies in numerical linear algebra, nonlinear algebraic systems and numerical methods in optimization. A second thrust concerns numerical algorithms for data analysis and statistics with the emphasis on robust procedures and the application of modern numerical analysis to these areas. Finally, there is a thrust in scientific computing and mathematical software aimed at research necessary to efficiently implement certain algorithms, including the automatic detection of errors in software and the testing and evaluation of competing routines.

C. Statistical Methods and Applied Probability

The main goal of this program is the development of valid theory and useful techniques for proper interpretation of data. The Army is constantly involved in testing and evaluating equipment to assess performance characteristics and predict reliability of these items. A recurring problem in these evaluations is uncertainty about the underlying model along with small sample sizes which are usually caused by high testing costs. In many cases, equipment is tested under deliberately imposed overstressed conditions in order to reduce testing time. These testing problems lead to many unanswered theoretical questions and practical difficulties in statistical estimation and inference. The methods of exploratory data analysis are helpful when the underlying model is not known. Many Army problems in target tracking and identification and logistics problems lead to data sets with many variables and unidentified parameters. Data sets with multiple outliers are also common. Monte Carlo simulations continue to be utilized in these problems. The program, therefore, mainly consists of research in computational statistics and data analysis, robust statistical methods, computer graphics and simulation, life testing and operations research.

D. Systems and Control Theory, Modelling and Artificial Intelligence

The main goal in this sub-area is investigations in mathematical system theory, modern control theory, stochastic modelling of dynamical systems and development of techniques for use in constructing intelligent systems for applications to a wide variety of Army applications. Topics of interest include algebraic and geometric approaches for large scale systems, adapative control, fast algorithms for estimation and filtering, distributed controls, knowledge representation and acquisition, control and search methods and systems and languages for symbolic computations.

E. Current Priorities

While the above descriptions reflect the current program, there are areas of higher priority among these. This, of course, does not mean that the Mathematical Sciences Division will exclude other proposals from consideration, but does reflect the Division's intentions to develop programs which take into account changing research trends as well as changing Army needs.

Currently, the high priority areas include adaptive methods for nonlinear partial differential equations and scientific computing, fast algorithms for real-time applications, data analysis and statistical computing, logistics, distributed and parallel algorithms, distributed networks and control and artificial intelligence.

METALLURGY AND MATERIALS

I. Introduction

Research supported by the Metallurgy and Materials Science Division is concerned with a broad spectrum of fundamental investigations in the various disciplines of materials science. The aim of this research is to discover the fundamental relationships which connect chemical composition, atomic and microscopic structure, processing history and resultant properties of materials. Although metals continue to dominate these programs, all classes of materials are of interest; e.g., polymers, ceramics, composites, electronic, magnetic and optical materials. Research on processing has the dual aim of processing novel materials with improved properties and of processing materials reliably, reproducibly and at lower cost. The behavior of materials exposed to complex loads in severe environments, as well as mechanisms or treatments to protect materials, is of interest. Development of test methods (destructive and nondestructive) which will be less expensive and will more reliably predict or simulate behavior of materials in service is also an important aim. Proposals which seek to tabulate physical, mechanical and chemical data without understanding the underlying principles will receive a low priority. Only when research has provided adequate knowledge about the constitution of materials and about their response to the various ambients encountered in service can the scientific design of new materials with predictable properties be successful.

II. Primary Objectives and Approach

A. Primary Objectives

To gain fundamental knowledge that will enable the synthesis and/or processing of high performance materials reliably, at lower cost, and with greater reproducibility;

To provide understanding that will form the basis for design and selection of materials that are strong, tough and resistant to severe environments (complex loading, ionizing radiation, chemical attack);

To determine the mechanisms and key materials variables that determine the electronic, magnetic, and optical properties of materials; and

To evolve efficient and reliable means to determine and assure long-term performance and reliability of materials.

B. Approach

In order to accomplish these primary objectives, individual work units are organized into the following subfields:

1. Degradation, Reactivity and Protection of Materials

2. Mechanical Behavior of Materials

3. Synthesis and Processing of Materials

4. Physical Behavior of Materials

The program in degradation, reactivity and protection seeks to discover the atomic/molecular/macroscopic mechanisms which limit the durability, stability and reliability of materials in service in hostile environments and during long-term storage. The program includes studies in corrosion, oxidation, hot gas erosion, environmental effects on polymer matrix composites, properties of interfaces including adhesion, thermodynamics and kinetics of materials-environmental interactions. Emphasis is placed on novel methods to protect materials from hostile environments in combination with complex states of stress. Examples include self-healing coatings, inhibition of corrosion, computer simulation/modelling of complex materials-environmental interactions, novel protective surface treatments, characterization of interfaces and adhesive bonding.

The program on mechanical behavior of materials addresses a wide range of topics to establish and provide understanding of the relationships between the structure of materials and their mechanical properties and how these relationships are influenced by environment, loading rate and state of stress. Major thrusts include behavior of materials under ultra-high rates of loading (such as shock and laser pulsing) to provide understanding of the behavior of voids, stress bands and spalling; thermomechanical processing of materials to reduce the inherent variation in mechanical properties, to provide deformation processing techniques for materials heretofore difficult or impossible to process and to provide materials with greatly improved properties; studies on fracture to obtain understanding of the fundamental mechanisms and materials parameters that contribute to fracture and to determine the influence of metallurgical structural parameters on fracture behavior in order to ensure enhanced fracture toughness in materials; studies on time-dependent mechanical behavior to obtain fundamental understanding of the mechanisms involved in fatigue, creep recovery, transformation hardening and to identify materials requirements necessary for ensuring enhanced resistance to deformation; nondestructive evaluation of materials to include the development of methods that can be used to evaluate the integrity of materials in order to quantitatively describe structural damage and to predict remaining life to avoid catastrophic in-service failure of materials.

The program on processing of materials includes research aimed at providing understanding of synthesis and processing of high-performance materials reliably, at lower cost and with greater reproducibility. Emphasis is placed on new classes of materials with improved microstructure, constitution and properties; improved understanding of the influence of fundamental processing variables on mechanisms of phase formation and development, microstructural evolution and resultant properties of materials. Trends in this subfield include nonequilibrium materials (to include rapid solidification rate processing); powder synthesis and consolidation; novel methods for processing ceramics; polymers and polymer matrix composites; elastomers; discovery of microstructural, compositional or other unique signatures which may be detected by nondestructive means and which may serve to enhance and control the processing of materials.

The program on *physical behavior of materials* includes research to provide understanding of *mechanisms and key variables* which determine the electronic, magnetic and optical properties of materials; to provide new electronic, magnetic or optical materials; to provide techniques to characterize these materials on the submicron scale; to provide novel processing techniques for these materials. Emphasis is placed on materials for microelectronics (VHSIC and beyond), especially electromigration, characterization of the microstructural and electronic nature of processing defects and metallization; rare earth permanent magnets and amorphous magnets; optical materials for detectors (e.g., HgCdTe), gradient optics; millimeter wave materials; radiation effects on electronic and optic materials.

III. Thrusts

A. Ultrahigh Loading Rate Effects on Materials

Examples of research included in this thrust are development of improved models of dynamic failure in metals, effect of materials factors in adiabatic shearing in metals, determination of the mechanisms of plastic deformation and failure, development of constitutive relationships in deformation and fracture in fiber-reinforced concrete and study of porous metals made by powder metallurgy techniques subjected to shock loading. The program emphasizes absorption and dissipation of energy by materials; failure models; role of phase transformation, surface properties and microstructure of materials in interactions with high-rate energy sources.

B. Novel Nondestructive Evaluation

This research is in response to the need for new concepts (rather than incremental advances in existing methods) to provide analytical capabilities for the detection of signatures of material defects, contaminants, microstructural characteristics, etc., that limit the performance, reliability and reproducibility of materials. Emphasis will be placed on quantitative analysis of absorbed hydrogen; polymers and polymer-based composites; prediction of remaining life in order to avoid catastrophic in-service failure; new techniques for detection of defects during processing and use of NDE techniques to control processing; new techniques for NDE of submicron electronic materials/devices.

C. Chemical and Biological Defense

The threat of hazardous chemical and biological agents led to this new thrust in 1982. The objectives of this program include effects of hazardous chemical and biological agents upon materials; use of materials to neutralize these agents; materials to protect personnel. Research emphasizes the following topics: effects of mechanical deformation on sorption and diffusion in polymers; stress-corrosion cracking of polymers; bonding of protective polymers to steel; electrochemical behavior of graphite-fiber, polymer-matrix composites; crazing behavior of glassy polymers in chemical agents.

D. Nonequilibrium Materials

This thrust is concerned with new materials which owe their existence to nonconventional processing such as rapid solidification rate, vapor-solid transitions, ion implantation, etc. Research topics include metastable microcrystalline and glassy alloys, role of undercooling in rapid solidification rate processing, dynamic compaction of nonequilibrium (rapidly quenched) powders, laser surface alloying, ion implantation, materials characterization, stability of nonequilibrium materials in severe or aggressive environments. Of special emphasis are methods for consolidation of rapidly solidified powders which retain their metastable microstructures and metallurgy.

E. Materials for Microelectronics

Research in this thrust will include electromigration, materials for metallization, processing of electronic materials, effects of defects on electronic behavior, characterization of atomic and electronic nature of defects, novel materials for microelectronics.

F. Magnetic Materials

The research in this thrust will include permanent magnets having high magnetic energy products (greater than 25 MGOe), fundamental mechanisms which determine coercivity in permanent magnets, inherent thermal compensation in permanent magnets and amorphous magnets.

Other important areas which exist as opportunities include gradient materials, critical and strategic materials (substitute materials, novel processing, surface treatments, etc.), manufacturing research, elastomers and millimeter wave materials. The foregoing areas of research are not intended to reflect all of the activities of the Metallurgy and Materials Science Division. We are always interested in novel concepts and phenomena in materials science which may have future applications for the Army.

Points of Contact:

Dr. Robert Reeber - Degradation, Reactivity and Protection; Critical and Strategic Materials

Dr. George Mayer - Mechanical Behavior of Materials

Dr. Andrew Crowson - Synthesis and Processing of Materials; Nonequilibrium Materials; Manufacturing Research

Dr. John C. Hurt - Physical Behavior of Materials; Electronic Magnetic and Optical Materials; Millimeter Wave Materials

PHYSICS

I. Introduction

The interests of the Army Research Office in physics research are generally focused in areas of atomic and molecular physics, condensed matter, cross disciplinary topics and classical phenomenology. We presently have little or no interest in relativity and gravity physics, the physics of elementary particles and fields, nuclear physics, astronomy and astrophysics.

The disciplinary boundaries of the Army Research Office are not sharply drawn as evidenced by the joint support of a number of efforts by the Physics and other Divisions. In addition, it is not at all necessary that a potential chief investigator be associated with a Physics Department to receive support by the Physics Division. For example, most of the ARO investment in laser research is provided by the Physics Division, with the overwhelming number of chief investigators currently in the laser program associated with Departments of Engineering.

The areas described in the following are intended to offer only broad outlines of interest by the Physics Division. New ideas may be generated which would cause major shifts of interest within or outside of the following areas.

II. General Areas of Interest

Well over ninety-five percent of the Division budget can be considered to fall within one of the following areas:

Atomic and Molecular Physics: In most general terms, we have interests in the electronic structure of atoms and molecules; spectra and the interactions of atoms and molecules with photons; atomic and molecular collision processes and interactions and studies of special atoms and molecules.

Condensed Matter (Structure): Areas of interest include the structure of solids; the mechanical properties of condensed matter; lattice dynamics, phase interfaces and thin films.

Condensed Matter (Electronic): This area includes electronic structure of the solid state and its electrical magnetic and optical properties. Topics of interest include electronic transport; electronic structure and electrical properties of surfaces, interfaces and thin films; a relatively minor interest in magnetic properties and materials; dielectric properties and materials; optical properties and condensed matter spectroscopy and a limited interest in the interaction of matter with particles and radiation. There are significant overlaps of interest between the Physics and Electronics Divisions related to solid state electronic device behavior.

Classical Phenomenology: Almost all of the Division interests in this area are related to optics and lasers. We expect to be developing increasing attention to infrared laser tunability, image formation and image processing. The Division has historically maintained a strong interest in nonlinear optics and its exploitation as, for example, in electromagnetic wave reconstruction by phase conjugation, spectral upconversion and optical bistability. At the present time, we do not have a strong interest in the topics of heat flow or fluid dynamics.

Cross Disciplinary Physics: A very strong interest exists in cross disciplinary topics including materials sciences, electromagnetic technology, and electrical and magnetic devices. As an example of interests within the materials sciences, the Division has provided support for physics of materials for infrared imaging, sputtered films for large area arrays and phase diagrams for HgCdTe. The development of near millimeter wave sources (see "Special Interest Topics") exemplifies our interest in electromagnetic technology.

III. Special Interest Topics

The following topics indicate a particularly strong interest by the Physics Division staff and represent greater than average opportunities for funding:

Near Millimeter Wave: The Division has a continuing interest in the development of near millimeter wave technology, especially in the region of 0.7 to 2.0 millimeter in wavelength. Although there will be continued support of source, component and detector development, more interest will occur related to signal processing.

Optical Processing: We expect that there will be increasing requirements for powerful techniques to handle data, particularly imagery, with a high throughput. Some of all of these applications will be dependent on the use of optical processing used independently or in conjunction with digital processing. The Division has interest in all research which will advance the state-of-the-art of optical processing technology.

Opening Switches: The development of repetitive opening electrical switches would have a major impact on the development of various weapons, electromagnetic acceleration and propulsion concepts, simulation experiments and other applications dictating the control of prime electrical power.

Ultrasmall Electronics: As the dimensions of electronic devices are reduced below one tenth of a micrometer, conventional electron transport theory is inadequate to describe the behavior of these systems. In coordination with the Electronics Division, the Division has a strong interest in research suggestions relating to the limits of speed and size in electronic device behavior.

IV. Physics Division Staff

The general areas of responsibility of the Physics Division staff are indicated below:

Condensed Matter, Dr. Charles Boghosian
Theoretical Physics, Dr. Mikael Ciftan
Lasers, Optics, Atomic and Molecular Physics; Dr. Bob Guenther

These areas are not sharply defined and any questions concerning the most appropriate contact should be referred to Dr. Robert Lontz, Director.